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ABSTRACT

This report on a symposium sponsored jointly by Unesco (United Nations Educational, Scientific, and Cultural Organization) and the Stanford University School of Education to foster understanding of the role of educational technology in educational systems and to identify needs for further research begins by summarizing international trends in the use of computers in education. The state-of-the-art of research in four areas related to computers in education is then reviewed: (1) policy making and implementation; (2) cognitive and motivational outcomes; (3) cost-benefit and cost-effectiveness; and (4) methodological issues. Policies and development, economics, and learning are identified as areas in which further research is needed, and unanswered questions and priorities for research at the international level are described for each of these areas. Suggestions for international cooperation and information exchange and conclusions reached by the participants conclude the report. The annexes include the reports of a working group on policy and development and a working group on learning, a list of symposium documents, and a participant list. (MES)

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Computers and Education: Which role for International Research?

A Report on the Stanford/Unesco Symposium
10-14 March, 1986
Stanford University School of Education

prepared by:

Martin Carnoy
and Liza Loop

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STANFORD SYMPOSIUM STATEMENT

Researchers from 18 countries, assembled at Stanford University from 10-14 March, 1986, at the joint initiative of the University and Unesco to examine the role of international research in the utilization of computers in education, have adopted the following:

People must be properly prepared to live in a society where most will encounter computers at workplaces, in private life, and in any other activity; we draw the attention of decision makers to their responsibilities in meeting effectively the new challenges to equity at national and international levels.

In recent years, more and more countries have been making decisions on a national level to ensure the introduction of computers in education on a large scale, and more decisions are in preparation in many other countries, both developing and industrialized. Educational authorities all over the world should take into account existing scientific evidence and apply scientific monitoring and objective evaluation to a rapidly changing domain.

A large body of knowledge has already been produced and could be made available with a little reorganization to countries wishing to use it.

Colleagues and researchers in various countries should cooperate in increasing the exchange of information as well as in making use of research methods leading to results that could be shared internationally.

International organizations, whether nongovernmental or intergovernmental, regional or worldwide, which are active in this field should increase activities involving exchange and cooperation, especially as regards future trends and prospective developments.

We declare our firm intention to promote research leading to a better mastery and greater optimization of the use of computers in education beyond economic and cultural differences. Therefore, we call upon all those concerned to join in developing intercountry cooperative research projects or internationally significant pilot projects.

This statement was adopted by those attending the Stanford/Unesco Symposium as a message to the international community on the importance of continuing research on the utilization of computers in education.

EXECUTIVE SUMMARY

COMPUTERS AND EDUCATION: WHICH ROLE FOR INTERNATIONAL RESEARCH

(1) The Symposium "Computers and Education: Which Role for International Research" was organised from 10-14 March by Stanford University under contract with Unesco, to examine the role of international research on the use of computers in education. Thirty high-level specialists from all over the world participated in the meeting. Amongst them, members of academies of sciences of Socialist countries, leading researchers in Western universities, heads of specialised journals on high technology for education and one representative of the World Bank.

FINDINGS

(2) There was a presentation and general discussion of the working documents prepared for the Symposium and particularly the background paper on research prepared by Stanford University. This debate revealed that if for many countries computers have been introduced, volens nolens, into educational systems, decisions to use them were not necessarily made as a result of research findings, nor did there exist a large number of research oriented projects, monitoring development or assessing the effects of computers in education. The discussion also underlined the gaps existing between the high level of expectations placed in computers, especially for learning and cognitive development, and the rather modest achievements which studies on the subject have brought to light.

(3) The Symposiumn further noted that most research studies have been undertaken at the micro level on small and limited experiments. A review of a number of these clearly suggests that the micro approach cannot answer questions at the macro level. The methodological difference between the micro and macro levels of research was a central point in the debate, participants stressing the urgent need to launch research at the macro level - research which should be both timely and developed with comparative methodologies to enable decision-makers to use the results.

(4) So far as studies on learning are concerned, one major problem would seem to be the lack of creativity in present applications. Computers are still used within the framework of traditional teaching-learning procedures. In the United States, for instance, computers are mostly used for drill and practice. Research is needed on the creative use of computers within new learning strategies and on applications with utility software, such as word processors and spread sheets, which would encourage and enable renewal of the teaching-learning process.

(5) The quality of national contributions, outlining specific policies or achievements, was high and lead to a rich exchange of views: France presented "l'informatique pour tous", whilst in the Federal Republic of Germany, computers in education are generally

reserved for technical and vocational applications, and in the USSR, general courses in computer science will shortly be available for all secondary school students.

(6) The case of developing countries was also central to the debates and was further developed during a panel presentation open to the public on "Education and Computers: an international approach". Those responsible for education in developing countries, despite the scarcity of resources, are well aware of their obligation to provide today's generation with access to computers to enable them to take their place in the "Information age". And, in turn, to ensure both equity of access and gender equality. Equity is a particularly acute issue in Latin America and Africa, where access to computers is economically stratified, children from higher income families having more access than others to computers. It is, therefore, especially important in these countries to ensure that access to computers in public schooling is raised to a level equivalent to that in private schools.

(7) Educational authorities in developing countries have a special responsibility so far as the development of computers and computer technology is concerned if they are to avoid increasing the gap with developed countries; education should be seen as a forerunner and not a consumer of computer technology and informatics ought to be developed through and not only within education.

OUTPUTS

(8) Policies and strategies should stress issues such as whom to teach, how to teach and what to teach. Research on planning, implementation and impact was given first priority, and particularly international comparative research (i) on the relationship between national information technology policies and the use of new technology in education and (ii) a critical survey of policy practices including educational aims, financial and organizational settings. Particular attention should also be paid to issues such as (i) strategies for private-government sponsored partnerships, (ii) quality and quantity of hardware, (iii) access to courseware (iv) teacher training and retraining. A special case was made for the need for evaluation of computer-based education in different settings in terms of cost-effectiveness using standardized variables to ensure comparability.

(9) If there is consensus concerning the introduction of computer technology in technical and vocational education, many countries appreciate differently the need for, the speed of development and the cost-effectiveness of computer literacy. There is little research in this domain on determining factors such as prospective development of labour in society, progress in computer technology, etc. Some specialists underlined that in a few years time, the use of computers will become as transparent as the use of a car, and that computer literacy is, therefore, given too much attention.

There was also consensus on the need to educate for life in an information society.

(10) Concerning learning, the Symposium pointed to methodological issues such as lack of reference points for evaluation. Existing

research is characterised by speculation rather than objective evidence, long-term effects often being predicted with no factual basis whatsoever. Attention should also be paid to the development of relevant culture-free assessment instruments which will assist in making cross-cultural comparisons. No conceptual framework exists to evaluate the relevance of results of observations in computer-saturated environments as compared to those obtained in computer-scarce ones.

(11) Research on the content of education should be directed towards such issues as (i) effects on the curriculum in various countries as the computer begins to play a role in social and economic spheres; (ii) the effect on the importance of intellectual skills of the advent of computer-based technology; (iii) specific computer applications to facilitate the learning of abstract concepts in particular dis ciplines; (iv) cross-cultural differences. Research on the effect of computers on the teaching-learning approach should cover issues such as (i) the minimum of new knowledge required to enable teachers to attain their own pedagogical objectives and (ii) the most robust models of teacher-computer-student interaction in an educational context and their utility in respect of educational goals, subject matter and resources.

(12) For the future, technological developments such as networking, down-loading from satellites, voice input and output, natural language processing, expert systems, etc., should be monitored in order to evaluate their potential significance for education in both developed and developing countries.

(13) Specialists from developing countries pointed to the lack of evidence that models advocated by technologically advanced societies have any relevance to their particular problems and pressed for more regional and sub-regional cooperation. Participants made several specific recommendations for international cooperation: (i) to develop a mechanism for exchange of information on meetings, publications and professional organisations, through dissemination of documents, directories, calendars of events and the organization of forums such as the Unesco International Congress planned for 1988; (ii) to examine the creation of a data base of research and project information in the form of a file in established information systems such as ERIC, EUDISED, or EURYCLEE; (iii) to launch an international programme to collect and disseminate parallel detailed descriptions of implementation processes and observed outcomes of noteworthy experiments on computers in learning in Unesco's Member States; (iv) to examine the creation of regional centres of excellence or up-grading of existing ones and to make available mobile teams and fellowship programmes on research in computers in education to developing countries; (v) to promote case studies emphasizing ethno-graphical methods and process analysis in order to assess cultural, economic and political factors; and (vi) to launch a cross-cultural, multi-year study on the effects of LOGO programming and the learning environment at the elementary and secondary levels.

(14) The Stanford Symposium Statement adopted by participants is addressed to decision-makers and international organizations in all countries, requesting them to take into account existing scientific evidence and to apply systematic monitoring and objective evaluation to this rapidly changing domain.

I. PROCEEDINGS

1.1. The symposium, conceived in 1983, was formalized in April 1985 during the second visit of the Director-General of Unesco to Stanford on the occasion of the 20th Anniversary of the Stanford International Development Education Program (IDE). The symposium was organised jointly by the Stanford University School of Education and Unesco in pursuance of Unesco's Approved Programme and Budget for 1984-1985. Stanford was considered a particularly suitable location for the symposium because of its proximity to Silicon Valley and its academic strength in computer science, learning theory using computers and educational applications of computers. In addition, IDE and Unesco have a long-standing relationship, cooperating in various projects.

1.2. In preparation for the symposium, the Secretariat organized specialized meetings in Tokyo (October, 1984), Abidjan (November, 1984), Damascus (March, 1985), Algiers (April, 1985) and Caracas (August, 1985). The findings of these meetings, together with those of other intergovernmental organizations in industrialized countries, have been synthesized in a working document, "The Use of Informatics in Education: present trends and perspectives". Stanford University prepared a working paper reviewing research on computers in education, entitled "Education and Computers: Vision and Reality in the mid-1980's". The Secretariat also presented a second working paper, "Informatics and Education: a first survey of the state-of-the-art in 43 countries".

1.3. Thirty high-level specialists from 18 countries from all over the world participated in the meeting. Amongst them, members of academies of sciences of Socialist countries, leading researchers in Western universities, heads of specialized departments in developing countries, two editors of specialized journals on high technology for education and one representative of the World Bank (see List of Participants).

1.4. The symposium was designed to foster a broad, worldwide understanding of the role of educational technology in educational systems and to identify needs for further research at the international level. Participants were asked to identify gaps and requirements in research at the national and international levels, to indicate possible research priorities with due attention to the role of international as distinct from national research, to propose ways and means of reinforcing information exchange between countries on research developments, and to promote joint inter-country or pilot research projects.

1.5. The symposium was opened on 10 March 1986 by Myron Atkin, Dean of the Stanford School of Education. His remarks were followed by an address by Etienne Brunswic, Acting Director of the Division of Educational Sciences, Contents and Methods of Education, Unesco. Hans Weiler, Associate Dean of Academic Affairs in the School of Education, presiding at the opening of the symposium, then called upon participants and observers to introduce themselves and give a brief resumé of their work on computers and education.

1.6. On 11 March, James Rosse, Stanford's Provost, extended the formal welcome of the University to Unesco and participants. In his

speech, the Provost underlined Stanford's international role and the appropriate choice of Stanford for the venue of the meeting: "Not only does Stanford have a long-standing relationship with Unesco and its international activities in the fields of education, science and culture, but Stanford has the leading School of Education in the country and the interface between education and technology has been at the very heart of Stanford's success as a major research university". He further stated that the "plans for this symposium were first discussed at a time when the United States was still a member of Unesco. After the United States government decided to withdraw from Unesco, Stanford reaffirmed its willingness to go through with these plans. Whatever the merits of the government's case against Unesco may ultimately prove to be under the impartial eyes of history, it is clear that the academic community of this country has every reason to continue to see Unesco as a valuable vehicle for interacting and collaborating with the world of learning and scholarship around the globe".

1.7. A steering committee (*) met during the symposium to develop the topics of the working groups, plan the strategy for summarizing their reports, and prepare a draft of the final statement.

1.8. The symposium was divided into three phases:

1. Presentation and discussion of the three papers prepared for the symposium, in order to improve the papers for final revision and eventual publication and to identify specific gaps in research on issues crucial to better understanding the present and potential role of computers in education. A number of participants had prepared written comments on the Stanford paper (see attached List of documents).

2. Two workshops, "Computers and Learning" and "Computers and Educational Policy" met for three half-days and two workshops, "Cost-effectiveness Analysis", and "International Cooperation" met for one half-day. A rapporteur for each group presented a written report to the plenary session.

3. Presentation and discussion of workshop reports in plenary sessions and the drafting of a symposium statement. The workshop reports formed the symposium participants' recommendations for future international research on computers in education. The final statement was the participants' "message" to the international community regarding the impertance of continued work in this field.

1.9. A representative group of participants gave a panel presentation open to the public on "Education and Computers: an international approach" on 13 March, extending the substance of the symposium's discussions to a wider audience.

1.10. The symposium was declared closed in the afternoon of 14 March 1986 by Etienne Brunswic, Unesco and Martin Carnoy, IDE and the School of Education.

(*) The steering committee was composed of Etienne Brunswic, Unesco; Martin Carnoy, U.S.; Henri Dieuzeide, France; Haruo Nishinosono, Japan; Fidel Oteiza, Chile; Mohamed Najim, Morocco; and Acad. T. Vamos, Hungary (for detailed affiliation, see attached List of participants).

II. FINDINGS

2.0. From the outset, participants indicated that research data available for the discussion was scarce and heterogeneous. Most research has been at the micro-level, related to small and limited experiments. Decisions to use computers were not necessarily made as a result of research findings, nor did there exist a large number of research oriented projects which monitored development or assessed effects of computers in education. The findings presented hereafter (i) trends in development in the field of computers in education and (ii) state-of-the-art concerning research, represent efforts to overcome the limitations and heterogeneity of available information and to present a global overview.

A. Trends in developments in the field of computers in education

2.10. Computers in education are used worldwide: (a) to meet a cultural objective generally part of a broader project of modernizing the productive base; i.e. to prepare children for an "informatics future", by developing an awareness of computers and how they work (computer literacy); (b) to prepare young people, particularly at the secondary and university levels, in programming and related skills for work in the informatics industry; (c) as an educational aid to improve students' skills in academic subjects at the university, secondary and primary levels; (d) curriculum development - introducing and developing changes in the content and methods of education through informatics; and (e) as an aid to teaching management and other skills in private industry and the public sector.

2.11 Different countries emphasize one or more of these uses, depending on the nature of educational policy-making, clarity of objectives and financial possibilities. The use of computers in education has, in the past, been supported by the private sector and pilot programmes have been launched by public education officials. One of the main obstacles to the introduction and development of informatics in education in most countries is lack of resources. This tends to restrict the use of computers in education in developing countries to experimental applications. Even in developed countries, utilization more directly related to labour market needs tends to receive better financial support than that related to the development of more general basic skills. The introduction of microcomputers in the last decade has substantially lowered hardware costs, but these costs are only a part of the total expenditure necessary to develop and maintain a well-functioning system of computer applications in education. The cost of software development, teacher training and on-going support must not be neglected.

2.12. Several papers describing national computer education policies were made available to participants (Australia, FRG, Hungary, USSR), as were comments on conditions in Bulgaria, Chile, France, India, Ivory Coast, Mexico, Morocco, Senegal and the United Kingdom. The quality of these national contributions, outlining specific policies or achievements, led to a rich exchange of views, e.g., France represents "l'informatique pour tous", in the Federal Republic of Germany, computers in education are generally reserved for technical and vocational applications, in the USSR, all secondary students will take general courses in computer science.

In the Soviet Union, a number of well-established pilot programmes in a few secondary schools that have been teaching principles of computer science and computer engineering for the last 15-20 years will be extended to all secondary school students in the 1985/86 academic year. The purpose is to impart information on computer science as part of general education, to provide some students with pre-professional training for future work in the field of computer science, and to acquaint teachers with the potential of modern computers. The course is currently being taught through textbooks and with some access to various computing systems, including the use of computers in nearby industrial and scientific centres. Increased availability of computers and software in the schools is under study. This will probably alter the way courses are taught. Thus, the Soviet Union is focusing on preparing an entire generation in computer literacy and computer skills, investing heavily in teacher training.

Hungary, like France, has installed a large number of micro-computers in secondary schools as a national policy. But, unlike France, the use of computers is not included in the regular curricula. In Hungary, computer use is optional. This has created much more interest in computing than had it been compulsory and students have become the driving force for computer education in schools. Furthermore, computer education has been introduced into military service.

In Bulgaria, an experiment is taking place in 29 schools. In textbooks for school children as of first grade, informatics is treated as an integral part of general education. Topics in the regular curriculum are taught taking into account the "Informatics Approach".

Mexico is also planning a large computer literacy programme in its schools, as is India. Both countries' policies are influenced by the autonomous introduction of computers in private schools and the recognition of the fact that the informatization of the world economy requires a computer literate population.

In most countries, computers are used principally in secondary and university education and, on a limited basis in primary education. Even in countries with national policies regarding computers in education, the number of computers in use in schools is small related to the number of pupils. In the countries with the most computers, the ratio of pupils to machines is still high: 34 pupils per terminal in the U.S. (where more than 90 percent of all schools had at least one terminal in 1985), and about 50 pupils per terminal in Canada. For other countries, the ratios are much higher. To facilitate software development, certain countries are moving to the standardization of equipment. Placement of machines varies, e.g., in the US and France, the trend is to establish computer laboratories in schools, rather than installing individual terminals in each classroom.

2.13. There is no universal agreement concerning the use of computers in education. Two of the world's most important computer-using nations (Japan, FRG), have moved relatively carefully on computer education, focusing primarily on training young people in computer

science at the upper secondary level, with limited introduction at the lower secondary level and little activity in primary schools. (2% of Japanese schools have computers; the main problem is the incorporation of written language into computers and computer software). There is the wider question of the need to invest massively in computer literacy in highly computerized countries. Regarding the beneficial effects of computer literacy, participants reflected a wide variety of positions, ranging from reserve to great enthusiasm.

In general education, computers are used as an aid in teaching general academic subjects, such as mathematics, science and language. Whereas it was originally thought that computers could provide an inexpensive substitute for teacher skills and that pupils would learn to use the computers by themselves (i.e. that microcomputers are inherently "children-friendly"), it has been found that, to be successful, computer assisted instruction requires considerable teacher training and that most children require help in learning how to use computers. Some teacher reluctance to engage in computer-assisted instruction, the lack of suitable software and the limited number of computers available in schools, have caused some countries, such as Australia, Canada, France and the UK, as well as many schools within more decentralized systems, such as the US, to de-emphasize CAI applications and to use utility software (word processing, file management, data bases and tabulators). Other computer applications in education centre on cognitive development and problem-solving; these are conceptually- and computer literacy-oriented, rather than skills-specific. The symposium discussion emphasized that the use of drill and practice versus problem-solving approaches depends very much on the dominant type of curriculum in a particular country.

At the upper secondary level, computers are used in teaching scientific subjects and as a means of training students in computer literacy, computer science and programming and increasingly in using word-processing and data-based systems and other workplace applications (e.g. service industries and commerce). One great penetration of computers has been in technical and vocational education, directly related to the economy's need for specifically trained labour, including the managerial level.

2.14. Software can rarely be shared and the use of imported products creates three types of problem: (a) unsuitability of software for the curriculum; (b) linguistic problems; and (c) cultural patterns inherent in the software, e.g. between Quebec and France. Many countries have embarked upon their own production, some on a national scale, (Scotland, France) and some in the form of a "cottage industry". In almost all countries in the Unesco survey, some educational software for schools is produced by teachers and more rarely by universities. Textbook publishers in some of the developed countries are entering into software production. In general, educational software production is decentralised and of poor quality; there is little quality control, lack of hardware standardization leads to difficulties of portability. Few measures have been taken by national planners and administrators regarding software distribution. New experimental distribution techniques are appearing, such as downloading software over data network links. Participants were especially supportive of "bottom-up" software development by

teachers, but stressed the need for quality control, standardization and well-developed distribution systems.

2.15. Few countries seem to have taken the necessary steps to prepare teachers to use computers, even when hardware is installed in schools. There is also little agreement on how to prepare teachers beyond short term courses (6-15 days) that merely help understand how to use computers in the classroom. The problems of implementing even this type of training are apparently great. Those countries most committed to computer training for teachers (Sweden, UK, France, Australia and Canada) have reached only about 25 percent of their teaching force. In most other countries, less than 5 percent of teachers have taken such courses (2 percent in Latin America). Even though some countries have recently launched national teacher training programmes (India, Chile, Korea, Cuba and Mexico), most are not devoting the necessary resources to training, but rather to purchasing hardware. Symposium participants emphasized that, since educational applications of computers depend on curriculum goals, effective training programmes have to be related to such goals. Longer training programmes to prepare teachers to develop educational software are considered desirable by many experts in computer education. These are expensive, even though the "pay-off" in terms of developing software may be high.

2.16. Schools within a country are not equipped to the same degree, creating problems of access for different groups of pupils. Primary schools are much less equipped than secondary schools, with no access at all for most of those attending school in most developing countries. Private schools are generally far better equipped than public schools and certain categories of public secondary schools better than others. In those countries in which computers in education are used to prepare future technicians/programmers and computer scientists/engineers, computers have been concentrated at the secondary and post-secondary levels. It was clear from the symposium discussion that the presence of computers in private schools in developing countries is pressuring policy makers to install computers in public schools. The discussion also suggested that more computers would soon be brought into schools even in the poorest countries, primarily due to the fear of being left behind in a world entering the computer age.

B. State-of-the-art concerning research

2.2. Research on policy making and implementation.

2.20. The papers prepared for the symposium and the subsequent discussions indicate a wide diversity of national policies and educational applications of computers, due on the one hand to widely differing or unclear objectives regarding the role of computers and on the other, to varying educational administrative structures (centralized versus decentralized).

2.21. Countries are increasingly formulating national policies regarding computers in education in response to the growing numbers of computers being used in the private sector and in response to political pressures of "national survival" in the face of a worldwide

informatics revolution. Such policies are usually necessary to introduce computers in public education because of the relatively high cost involved. The introduction of computers requires equipment, teacher training, software development and curricular coordination to maximize results.

2.22. Implementation is highly diversified within levels of schooling and among different types of schools. Very little is known, however, about the "quality" of implementation, even when hardware is available and the computers are being used, or about the minimum exposure necessary to ensure qualitative change in student learning. Research reports suggest that quality of implementation is linked to teacher training, availability of software, and good articulation between training, software and curricular objectives.

2.23. The research review presented to the symposium identified four levels of access, ranging from continuous access to a microcomputer provided with necessary software and instruction at one end of the spectrum to one-time access at the other. Research reports suggest that even in the most developed computer education systems, in highly industrialized countries, the majority of pupils have a level of access in which either proper instruction, adequate software or time at the microcomputer are in short supply or one aspect is totally absent. Beyond calculations of "theoretical" time spent annually by the average pupil at the microcomputer, neither estimates of access at the national level nor estimates for differential levels of access by social group (race, sex, socio-economic class) within a country or comparisons between countries are available.

2.24. Participants also raised the issue of "cognitive access" which is defined as the extent to which the available hardware and software serves the cognitive needs and expectations of the potential user. It thus emphasizes the role of the learner and the learner's interaction with that technology. It was argued that if computers are to become everyday features of our environment, and hence possess the potential to influence learning, it will not be sufficient simply to increase numbers and make them available to both students and teachers. The educational objectives must be attained, because failure to meet these objectives will result in the ultimate failure of the technology and rejection by the educational community.

2.25. Research on implementation is also directed towards how computers are used in instruction. The section on trends suggests that most countries still focus on vocational instruction with computers. However, as microcomputers spread both at the secondary and primary levels, computers are used as a means to achieve computer literacy and to enhance general learning. The latter application holds the greatest hope and interest for educators, although from the standpoint of national economic and social policies, vocational applications and computer literacy may have a much greater priority.

2.3. Research on cognitive and motivational outcomes.

2.30. Relatively few studies measuring the effects of computer-assisted instruction on learning exist outside the US and UK. Because most of the studies have been in the US where education emphasizes

drill and practice, research on cognitive effects is concentrated on drill and practice applications.

2.31. The results of two recent meta-analyses of a large number of CAI micro-studies show no significant differences compared to traditional teaching methods, whereas another analysis shows moderately high differences. Computer simulated experiments where pupils investigate relations between variables in models pertaining to social or physical reality produce the largest cognitive gains.

2.32. Reports also suggest greater gains for those who are least successful with traditional teaching-learning systems. Other reports indicate a declining effect the longer the length of instruction. Others suggest that CAI reduces learning time. Recent work presented by Stanford participants showed significant gains in academic skills among kindergarten pupils using computers, especially when school use was supplemented at home and substantiated that those with lowest academic skills show the greatest gains.

2.33. Similar evaluations of LOGO in the US also yield mixed results. Some studies showed significant gains in problem-solving skills, including gains in divergent and reflective thinking. But a major two-year study of LOGO found no significant effect on cognitive skills.

2.33. CAI would appear, then, to increase cognitive skills, but the form in which it works best is not yet clear. Two general trends were evident at the symposium:

(1) away from BASIC programming, towards mastery of application tools such as word processing, spread sheets and data bases;

(2) away from rote drill and practice towards development of creative problem-solving skills.

2.34. Research on the motivational effects of computers on learning is even more limited than research on its cognitive effects, but recent studies suggest that several aspects of modern tutorial software, particularly the fantasy element, could make the subject matter intrinsically more interesting and hence could increase learning. Other studies indicate that motivation to learn particular subjects can be increased by using computers

2.35. There is a lack in all studies of an underlying theory of learning that can explain why or why not computers will enhance learning. Papert's seminal work is as yet unsupported by firm data. The claim that learning with computers will create new conceptual skills in children has to be supported by evidence. Because learning with computers is at its inception, its effects may take a generation or two to be felt.

2.4. Research on cost-benefit, cost-effectiveness

2.40. Studies of costs, cost-benefit and cost-effectiveness of computers in education are limited.

2.41. One of the problems of measuring costs in developing countries is to assess the real costs of maintaining and using a computer-based

learning system. At present, most computers are used in environments where maintenance and use infrastructures are well-developed and there is a market for such services (hence they can be priced). In many developing countries this is certainly not the case.

2.42. Cost-benefit can be applied to the use of computers for vocational training purposes, where there is a measurable material benefit to society in training people in computer skills (higher earnings and productivity of those who are trained) and to the use of computers for computer literacy (value to the society of having a population familiar with computers and their use). The advantage of cost-benefit studies is that if agreed-upon values can be placed on the benefits of different projects, the cost-benefit ratios can be compared. Cost-effectiveness can be used to evaluate computer-assisted instruction in comparison to other technologies (educational radio, books) in terms of increases in cognitive skills associated with each technology and its costs.

2.43. Cost-effectiveness studies made to date on CAI (no cost-benefit studies are currently available) suggest that the costs of CAI systems can be measured and that CAI can be compared with other technologies. Results are too sparse, however, to indicate whether CAI is more or less cost-effective than other learning technologies.

2.5. Methodological issues.

2.50. Most research studies have been undertaken at the micro level on small, limited experiments. A review of a number of these suggests that the micro approach cannot answer questions at the macro level. The methodological difference between the micro and the macro levels of research was a central point in the debates, participants stressing the urgent need to launch research at the macro-level - research which should be both timely and developed with comparative methodologies to enable decision-makers to use the results.

2.51. Evaluation of the effects of computers on learning is needed to distinguish between what may be classed as beliefs as opposed to well-founded experimental observations. Evaluation should involve both formative and summative methods and be carried out by independant researchers.

2.52. Many current assessment studies use traditional evaluation methods (comparative groups) and are culturally biased. Attention should be paid to the development of relatively culture-free assessment instruments that will allow cross-cultural comparisons, based on measurement of both specific knowledge and competence outcomes, and evaluation of general motivational and socio-cultural impacts.

2.53. Evaluation of the effects of computers is situated in a particular cultural context which must be discussed as part of the evaluation methodology. New approaches to assess effects should be applied, especially case study and historical, ethnographic methods that permit effects to be situated in cultural-historical contexts.

2.54. Much can be learned about the use of computers in education from experience with other technological devices, such as radio and television. Many studies have been made of these other educational media in developed and developing countries which deal with problems of introducing technological devices in education and their effects on learning and the cost-effectiveness of using media as compared with improving traditional teaching, including the use of textbooks. How does computer education compare with radio and television?

III. SUGGESTIONS FOR FUTURE RESEARCH ACTIVITIES

3.0. Participants determined three priority areas in which research is needed to assist and facilitate the use of computers in education: (1) policies and development; (2) economics; (3) learning.

A. Policies and development

3.10. Although countries may view differently the role of computers in society, nearly all face the challenge of developing policies to assist their citizens to enter into the Information age and, therefore, need to evaluate the educational uses of computers. This poses a special problem since the computer was not developed as an educational tool, but rather to increase productivity in various work situations. Educational planners in most countries do not control the technology of the hardware being developed nor, to a large extent, software development. Education ministries, school districts and school administrators need to define goals for using computers in education and develop implementation strategies in terms of finance, educational effectiveness and equity - the "how", "what" and "who" aspects of a particular policy.

Gaps and unanswered questions

3.11. Participants stressed the great diversity of strategies already existing: some countries focus on the preparation of youth and adults for careers in computer-related jobs and for life in an information society; others are beginning to use computers to assist in learning basic course materials; that is, to increase the productivity of instruction. Each of these strategies implies reaching a different set of individuals in a society with computer-based education: those strategies aimed at primary schooling will reach the largest group and those aimed at specialist training of computer science, the smallest. Research has not provided much information on how to decide between these different strategies, leaving many unaswered questions.

3.12. Research has indicated that, in the short term, training people for jobs using computers and teaching people about computers is more cost-effective than using computers as an instructional aid. But what are the criteria for establishing national priorities for using computers in such training? Under what conditions should a society invest in the highly specialized training of computer specialists? For large-scale mass instruction in computer use, what practical skills should be emphasized? These may include workplace applications, such as management, engineering uses in drafting and design, cybernetic or control implementations, mathematical analysis, statistics, database utilizations and word processing. Under what conditions should consideration be given to educating the citizen-consumer for life in an information society? Or to provide access to general information through computers as a way of fostering that information society, including the skills necessary to use computer-based administrative services and teaching individuals how to protect themselves against computer invasion of privacy (computer rights and computer law). Participants showed concern about community outreach programmes. Should there be national and local awareness programmes on computers in education for parents and the local community?

3.13. How much time with the computer is considered adequate to attain each educational goal and how does this affect policies on using computers to reach different groups for different purposes? In the most coordinated, systematic national policy to date, France has implemented a massive, centralized effort to provide "Computers for All", installing one computer for seventy pupils in each school and training 150.000 teachers, at a total cost of US$200 million. Is even this "adequate"? For countries with scarce resources, it is not possible to provide nearly this much computer access to all pupils. Which pupils should have such access and how much is adequate? Is there an order of priority for introducing computers into different levels of education - university, secondary, primary - for different educational objectives?

3.14. Computer education may also take place in a variety of institutional or environmental settings: e.g. industry, government offices, military training, televised instruction, clubs and youth organizations. How effective are these alternative settings in reaching specific target populations?

3.15. What has been learned about the advantages or pitfalls of developing computer-based education of different kinds in different ways from the information now available on computer-based education in its various forms in different countries?

a) Are there thresholds of investment in teacher training or software availability necessary before computer education of different types becomes effective? Are there particular configurations of hardware/software/training that seem especially effective or ineffective? Is centralized or decentralized management more effective in certain settings? Does the local planning and implementation of computers in schools (as in the U.S.) produce better results than nationally planned and implemented computer installations in education (as in France)? Does lack of coordinated national policy help or hinder effective implementation?

b) Are pilot programmes transferable to "average" populations? It was suggested that large-scale "high visibility" demonstration projects might be of value in themselves, even if they are not transferable, by drawing national attention to the benefits of computer education. Is this the case? Do large-scale projects (as in France, for example) generate a favourable reaction to computers in education?

c) There is a universal need to train educators in the use of computers in education, including pre-service training of teachers and administrators. What kind of support structure is necessary to train teachers, and what general infrastructure is required to encourage institutional initiatives to introduce and/or maintain computing?

d) What are the most efficient ways of developing courseware? Government sponsored approach, private (market-oriented) or a combination of both? Design at school level by teachers or in specialized institutions by highly professional teams? Under what circumstances can software be adapted and imported? What are the most cost-effective solutions for distributing and maintaining software packages which have been given a good evaluation? There is consensus on the need for evaluation: by whom? towards what goals? and how can objectivity be ensured?

3.16. Particular emphasis was given to the fact that computer implementation differs according to the culture, political system, status of students, availability of financial resources at various levels of the system. There may be no single correct model of implementation, but rather various models appropriate to different environments. Is it possible to develop criteria to identify the conditions under which certain models are more effective than others?

Priorities for research at the international level

3.17 Symposium participants divided policy-making research into "evaluation" and "planning" components, based on critical surveys of present practice to help planners and administrators involved in making computer implementation choices.

Under "evaluation", emphasis was placed on a comparative "case study" approach, since most countries are in the initial stages of implementation and detailed measures of experiments and pilot programmes are not feasible. Such case studies should be made of comparable implementations - cases of computer literacy programmes, for example or computer-assisted instruction - with particular attention to the initial criteria, goals and modes of implementation. Each case study should attempt to respond to questions posed under the section on "gaps and unanswered questions" (3.11-3.15). The subsequent international comparison should attempt to draw general conclusions, taking into account differences in culture, political conditions, language and goals. Comparative evaluation research would also include comparisons of cost-effectiveness of various educational applications of computers (see "economics" research 3.20.)

3.18. Under "planning", six areas of possible international co-operation were identified:

(a) Comparative studies of computer implementation at the national, regional or local level to identify management structures and combinations of teacher training and software development needed to achieve maximum effectiveness in attaining desired goals. The studies would focus on the possibilities and impact of private/public partnerships in teacher training, software development, and delivering the training itself (business-centred combined with school-centred computer education).

(b) Comparative analysis of the relationship between national economic and social planning and the use of computers in education. Such analyses should aim at improving information about those computer applications in education most appropriate to more general national objectives. They should also discuss the influence of hardware manufacturers and the role of parents, the community and other social institutions.

(c) Comparative studies of the priorities for investment in computer education (vocational/CAI/computer literacy) in different social, economic and cultural contexts. Who sets priorities and how does this influence the success of projects? Do computer education projects develop spontaneously in most countries through industrial and business use, or are priorities largely the result of national

policy planning with well-defined goals? This type of comparison could serve as a guideline for countries moving towards choices in larger-scale computer implementation.

(d) Comparative analyses of teaching methods for vocational training (in formal education, industry and other training locales); for computer literacy (in schools and in other organizations), for computer-assisted instruction (using different forms of CAI); and how to best integrate computers into the curriculum.

(e) Comparative studies on staff development: should one concentrate on producing large numbers of computer-literate teachers in various academic subjects, and/or should a new kind of computer "specialist" teacher be trained, who focuses primarily on computer education? What are the cost implications?

(f) An international study of possibilities for and methods of international cooperation (including computer information networks). What activities could best assist educators, planners, administrators, researchers and teachers involved in computer education projects? For example, sharing new knowledge of teaching and training methods, exchanges of teachers and researchers, developing software (can language and cultural differences be overcome?), organizing cooperative evaluation projects, and disseminating research results. What kind of cooperation would promote research on computers in education in developing countries?

B. Economics

3.20. Each workshop discussed the importance of costs in assessing educational applications of computers. Computers are expensive. The introduction of the micro-computer and the possibility of continuing reductions in hardware costs in the near future have helped. The cost of teacher training has generally been underestimated. Software development is a crucial and expensive input to computer education.

3.21. To introduce computers into education, educational authorities must take decisions about the kind of computer education to introduce, to what extent and what combination of hardware, software, teacher training to use. One important element in such decisions is cost-effectiveness or cost-benefit analysis. Such economic analyses define the relative efficiency of different projects in terms of the stated objectives of planners and educators. It is always important to bear in mind that these analyses cannot be undertaken without well-defined objectives.

Gaps and unanswered questions

3.22. A review of literature and subsequent discussion indicated little information on cost-effectiveness and cost-benefit analysis of computers in education. The little research that does exist suggests that costs can be measured and that such analyses can be carried out with existing methodologies.

3.23 The workshop on economic aspects emphasized that certain conditions must be met in such studies. (a) There must be agreed-upon objectives. (b) Cost-effectiveness studies should measure

cost and effectiveness together as part of one study. (c) Cost measurements should be standardized to make the results of the different studies comparable. (d) Cost measurements must not be limited to the cost of the computer and the courseware. The effects on the "traditional" costs of the system have to be evaluated as well - teacher training and retraining, change in the number of teachers needed, maintenance and operating costs, etc. (e) Costs should be classified according to sources of finance, because computers might, in some cases, be a way to shift part of the financial burden of education. (f) Costs should be classified according to the different parts of the teaching process involved in order to pinpoint causes of cost differences, (g) Research should distinguish between the planned costs and the actual costs of a given project.

Priorities for research at the international level

3.24. The participants proposed that cost-effectiveness and cost-benefit studies be promoted in various countries as the beginning of an on-going evaluation process to assess which computer education projects are most productive per unit cost and why. It would be of great value to organize an international seminar on cost-effectiveness and cost-benefit analysis and also to work with researchers to disseminate not only the results of the methodology developed at such a seminar, but also the results of the empirical studies themselves.

C. Learning

3.30. The literature review and workshop discussions revealed a number of areas in which research was lacking and more information needed at an international level before systematic decisions are taken regarding computers and learning. In many domains, the assessment of the effects of computers is problematic since there is a lack of reference points for evaluation. Claims of the computer's ability to accelerate intellectual development in children have no simple parallels in traditional education. There is considerable debate around the effects of generalized use by children of computers on their social and psychological behaviour. Long-term effects are often predicted with no factual basis whatsoever. No conceptual framework exists to evaluate the relevance of results obtained in a computer-saturated environment compared to those obtained in computer-scarce ones. Recognition of these gaps led the group to formulate certain questions particularly appropriate for international research.

Gaps and unanswered questions

3.31. More needs to be known on the impact computers will have on the educational system as their use spreads. What are the effects of computers and an informatized society on school curricula? How might educational objectives and pedagogy change with the widespread use of computers? Do some intellectual skills lose their importance in an informatized society, whilst others gain? There is little research available on the impact of computers on what is taught and how it is taught. Do computers introduce new subjects or new content

into the curriculum? Do they introduce new ways of teaching existing subjects? Does use of computers emphasize different intellectual skills to instruction without computers? Some research shows that computers facilitate the acquisition of certain skills more rapidly and possibly earier in the learning process. Is this true of all cultures and social groups? Equally for males and females?

3.32. Where computer literacy is a goal, research is needed on the differential benefits associated with alternative modalities of implementation. The effectiveness of various modalities, such as courses about computers, experience with utility software and using computers to teach traditional school subjects, courses in programming and mass-mediated information should be evaluated.

3.33. To what degree are different types of computer applications in learning more or less appropriate to each educational level? Discussions emphasized that different types of computer applications may be relevant and effective in educational systems or situations with different curricular objectives. What are the differential effects of computer-mediated learning strategies and software which are based on competing patterns of human learning? Is any factor more important than another in determining the type of application? For example, is drill and practice preferred by teachers with little training because it is easier to use? Is some software more "teacher-proof"? What are the most robust models of teacher-computer-student interaction and how does their utility vary with educational goals, subject matter and resource factors?

3.34. What is the minimum amount of new knowledge required for teachers to meet their own pedagogical objectives? What is the role of the teacher within the contexts of various scenarios of computer-mediated learning inside and outside the classroom?

3.35. The controversial issue of longer-term effects of computers on learning and reasoning was also considered an important subject for research. How can research evaluate such effects and the motivation to learn? What are the long-term effects on learning of problem-solving software, such as LOGO? Does LOGO have a different effect on reasoning skills according to the cultural or curricular setting? What is its longer-term effect on reasoning skills and thought patterns?

3.36. Participants also discussed the possible effects of innovations in hardware and software. For example, the use of artificial intelligence and educational expert-systems, voice input and output, cheaper and more powerful hardware and communications could all change future educational applications of computers. They could also significantly modify educational theories, curricula and the role of the teacher.

3.37. The workshop stressed that more research is needed on evaluating computer-assisted instruction in different cultural contexts, for different social groups, for males and females and its effects in different subjects at different educational levels in different socio-cultural settings. More needs to be known about the relationship between culture and the effects of computers on learning. Are computers more or less likely to improve learning in

different cultures because their feedback to students is "objective" rather than "subjective". How does the degree of access to computers affect results?

Priorities for research at the international level

3.38. Cooperative projects to study various approaches to computer literacy, like the cooperative project between Switzerland, the Netherlands and several German States (FRG) on computer literacy. How could countries within limited resources widely and rapidly disseminate familiarity with and knowledge about computers using modalities such as courses about computers, practical experience in the private sector and in schools and experience with CAI in other subjects? Such studies should also analyse the effectiveness and cost-effectiveness of approaches providing familiarity with computers (which requires a definition of "familiarity").

3.39. An international seminar on the evaluation of computer-assisted instruction would contribute to the development of evaluation research, especially in developing countries. Evaluation criteria applied to technological advances in computer-based applications for learning are largely based on those market factors, cost factors and social objectives which are prevailing in a few industrialized countries. There is an urgent need for the formulation of evaluation criteria based on learning environments which are broadly applicable in the international community.

3.40. Comparative studies of CAI projects in various countries could help understand trends in the use of computer-assisted instruction, what is behind those trends, and the relationship between the type of CAI used, socio-cultural setting, curriculum objectives, the degree and type of teacher training and availability of software. International comparative studies would enable researchers to understand how national curriculum objectives and various CAI methods interact.

3.41. A cross-cultural, multi-year study of the effects of LOGO programming and the learning environment at the elementary and secondary level was proposed. Information about the long-term consequences of computers on learning is inadequate. LOGO is a case of a fully promoted application which has clearly specified and attractive theoretical objectives. Such a study could take into consideration many of the research questions raised in the workshop.

IV. SUGGESTIONS FOR INTERNATIONAL COOPERATION AND EXCHANGE OF INFORMATION

4.0. The main task of the workshop on international cooperation was to analyse how best to achieve the interaction and communication necessary to promote international research on computers in education. Participants began from the basic premise that the goal of such cooperation is to maximize international exchange of information and to promote research on the educational applications of informatics.

4.10. Comparative evaluation of educational applications of computers was not practicable until hardware and software were sufficiently developed to provide subjects for study. Increasing numbers of students in many countries are now experiencing the effects of computers. Researchers are beginning to produce scientific evidence that can be used by policy-makers and other researchers, at least in planning more comprehensive research projects. The rapid worldwide growth of large investments in computers in education and the existence of on-going pilot projects in different contexts indicate the need for coordinated international research, both to promote national studies and to compare their results in a systematic and cumulative way.

4.11. Participants stated that computers and informatics afford a special opportunity for organized, worldwide, intellectual cooperation. International research could help in solving problems related to transcultural difficulties and technological gaps. A major reason to promote international cooperation in research is the benefit to be gained from examining different examples of computer applications. A better picture of the nature and effects of computer-based intervention could lead to the formulation of informed recommendations for research and implementation.

4.13. Comparative studies could reveal inter-relationships between variables that national studies cannot. International research can also compare national policy-making, cumulate and analyze information on micro-studies, and provide objective guidelines to educators and planners that national studies alone may not. The conclusions of international research should be applicable, or at least of interest, to many nations.

4.14. Systematic exchange of information can guide national research. Guidance will help avoid duplication. The Stanford Symposium showed that in almost every area researchers are just beginning to understand what is involved. International research at such an early stage can play an important role in helping to point researchers and planners in fruitful directions.

4.15. Specialists from developing countries pointed to the lack of evidence that models advocated by technologically developed societies have any relevance to their particular problems. Regional cooperation in research on the use of computers in education could, therefore, be particularly significant where similarities of culture, economy and policies exist.

4.20. The group's deliberations paved the way for discussions on the improvement of research interchange and systematic international communication among researchers. Participants made the following specific recommendations:

4.21. To examine three different approaches as possible bases for promoting research and interaction between national institutes: informal networking among researchers at national institutes using existing or improved networking arrangements; creating new, or up-grading existing regional centres of excellence to promote interation among researchers in regional and international research projects; making available mobile teams of experts to researchers in developing countries to assist in formulating research projects and providing fellowships for research on computers in education.

4.22. To develop a mechanism for exchange of information on meetings, publications and professional organizations, through dissemination of documents, directories, calendars of events and the organization of forums, such as the planned 1988 Unesco International Congress.

4.23. To examine the creation of a data base of research and project information in the form of a file in established information systems, such as ERIC, EUDISED, or more specifically EURYCLEE, the software data bank created by the European Community, and the use of electronic mail to disseminate this information.

4.24. To launch an international programme to collect and disseminate parallel detailed descriptions of implementation processes and observed outcomes of noteworthy experiments on computers and learning in Unesco Member States.

V. CONCLUSIONS

5.1. The increasing importance of informatics in various sectors of the economy has resulted in the appearance of computers in education in both industrialized and developing countries. Most decisions to introduce computers in education have been made without considering the various implications of this particular technology and its cognitive and developmental effects, without previous research and without weighing the merits of research undertaken elsewhere. Policy-makers, curriculum developers, educators and parents are all faced with the following challenge: on the one hand, they want to provide computer experiences for children in the classroom as a key factor for life in modern society but, on the other, so far they have no conclusive evidence of a general nature that the computer is a positive educational force, worth an enormous investment in hardware, software and teacher retraining.

5.2. The worldwide recognition of the importance of computers makes it imperative to revise educational curricula to include informatics components. But, whereas there is consensus concerning the introduction of computer technology in technical and vocational education to prepare specialists in programming and computer science, it appears that many countries differ on the need for, the appropriate speed of development, and the cost-effectiveness of computer literacy and computer-assisted instruction in general education. There is a lack of research on the need for, or value of, such wider applications of computers in education. Such research as does exist, for instance on the cognitive and motivational effects of computer-assisted instruction, has produced such mixed results that it is difficult to draw any definite conclusions for policy. Among countries where computer technology is widely used in the various sectors of society, some users, such as Germany and Japan, have taken a much slower, reserved approach to general computer education than some others like France, the United Kingdom, the Soviet Union, Hungary or (in a much more decentralized and uncoordinated manner) the United States. Although the price of hardware has fallen rapidly, for most developing countries an investment in generalized computer education, even limited to secondary schooling, is sizeable enough to require serious reflection on the cost-effectiveness and cost-benefit of such an investment.

5.3. The development of computers in education raises issues of equity both within and between countries. Gender equality in computer access and training is of special concern in all countries because of indications that young women are not receiving the same degree of access as young men. Equity is a particularly acute issue in Latin America and Africa, where access to computers is economically stratified, children from higher income families attending private school having much more access than others to computer education. In addition, then, to the argument that developing countries will be left behind in the informatics revolution if they do not invest heavily in computer education, policy-makers and educators are pressed by equity considerations to ensure that computer education is not made available only to a priviledged few. Educational authorities in developing countries have a special responsibiltity in that they must avoid increasing the gap with developed countries; education should be seen as a forerunner and not a consumer of computer

technology and informatics ought to be developed through and not only within education.

5.4. Computer education with the specific purpose of equalizing learning possibliities for academically disadvantaged groups could be one of the most powerful elements in overcoming present shortfalls in national educational systems. Research results suggest that lower achievers have greater cognitive and affective gains with computer based applications than higher achievers, implying that the very groups having least access to computer education may be the ones who can profit most from it. Similarly, more research is needed on the role of computer education in equalizing opportunities for special and isolated groups presenting difficulties for traditional educational systems.

5.5. The Symposium stressed the need to educate for life in an information society. Participants were especially concerned that individuals learn simultaneously to protect themselves against invasion of privacy by the computer and to exploit the potential that this same technology represents for expanding their participation in decision-making and self-realization.

5.6. The potential significance for education of changes in computer technology should be borne in mind. Research on computers in education is evolutive by its very nature: new technological developments can significantly modify the conditions of computer use and very rapidly render research findings obsolete. Of particular interest for education are voice input and output, natural language processing, expert systems and intelligent tutoring, advances in networking and down-loading from satellites. These developments could affect the physical configuration of the educational system and the distribution of costs and benefits.

5.7. The Stanford Symposium Statement adopted by the participants stresses the need for and the role of research in the development of computers in education. Researchers are producing a body of knowledge which could already be used by educational authorities all over the world to back their decisions. Scientific monitoring and objective evaluation must be applied in such a rapidly changing domain. Research contributing to better mastery and greater optimization of the use of computers in education could help decision-makers to face the new challenges of the increasing development of computers in society.

ANNEXES

Report from the group "Policy and Development"

POLICY DOCUMENT ON COMPUTERS IN EDUCATION

PREAMBLE

Whereas nations of the world may have differing views of the roles of computers in society, nearly all countries are now challenged to develop a policy for the "information age". For many countries the time is now -- and for others, it is coming -- entire populations are coming into contact with computers. For some this is in the workplace, for many it is in their roles as consumers or citizens, and for a few, this contact will be in the form of an "expert," the individual who designs and builds computers and their programs. For students, the computer may have great influence upon instructional process and upon their educational program.

Essential to all governments is the need to evaluate the uses of computers in education; teaching with computers and teaching about computers. This includes goals, costs, implementation strategies, equity, and particularly the "whom", "how", and "what" aspects of their educational policy.

I. WHOM TO TEACH?

The greatest number of students who would benefit from computer implementation schools will be those in primary and secondary

education programs, followed in number by students in advanced education programs. These are characteristically the non-specialist student applications that reflect one or two goals: (1) computer implementation to assist instruction in basic course materials -- that is, to increase the productivity of instruction, and (2) implementation in order to teach about computers as a topic of instruction -- as in "computer literacy".

A relatively small numbers of advanced students will become specialist "computer scientists" and their curriculum is much different than the more universal applications described in the above paragraph.

Other students to benefit from computer instruction are adult groups who may be taught practical uses of computing in order to enhance their occupational skills.

II. HOW TO TEACH ?

A first question is to determine the degree to which computing, relative to the implementation of other instructional technologies (new textbooks, television, special teacher training), is to be given priority. It should not be assumed that educational computing will always be a beneficial investment.

One goal, as has been stated previously, is the integration of computers as instructional tools in basic subjects, such as reading, writing, and mathematics. This may be considered as

"Computer-assisted instruction", but refers to many applications, such as simulation or problem-solving, and not just "programmed" learning.

The second main goal is for the purpose of learning the skills with which to use the computer, often referred to as "computer literacy." This latter term, too, can be given a broad definition so as to include not just detailed use of the computer in various situations, but a general knowledge of the roles of computers in society (the broad use is sometimes referred to as "informatics").

It is recognized that computer implementation may be quite different according to the culture, socio-political system, the status of students, and the economic capabilities to carry out the implementation. That is, there is no single "correct" model of implementation, and is primarily dependent upon a given environment.

It is also recognized that computer implemention may take place in a wide variety of institutions or environments in addition to the school, namely; in businesses, in government, in military training, in public education programs, including televised instruction, and in volunteer education programs such as offered by clubs or youth organizations.

III. WHAT TO TEACH?

Given the computer as a topic of instruction (that is, beyond its use to facilitate instruction in other subjects), there are important questions of priority to be researched

1. What national investment is warranted for the highly specialized training of computer scientists?

2. For large scale mass instruction, what practical skills for computer use should be emphasized? These may include workplace applications such as in business management, engineering uses in drafting and design, cybernetic or control implementations, mathematical analysis, statistics and database utilization.

3. What consideration should be given to educate the citizen-consumer for life in an "information society.?" This includes the skills necessary to use computer-based administrative services such as ticket booking, banking, electronic mail, and other new applications (e.g., identity cards, passports, driver's licenses). Further considerations should include policy relative to free access to information in one's community and on government issues, personal privacy, and rights to files on personal information.

IV. HOW TO PLAN?

It is increasing recognized that the challenges to planning computer implementation in education are in the area of

professional development of personnel (preservice teachers, inservice teachers, administrators and teacher trainers) programs ("software") and equipment ("hardware"), curriculum development, consultancy services, involvement of local industries, awareness programs for parent and general community, and so on.

It is important to include in the planning process those individuals who will be directly involved in managing and using the computers. Most implementations, however, underestimate the importance and costs of personnel training.

Many benefits can be gained from examining other examples of computer implementation, particularly those where there are similarities in the culture, the economy, or the political system. (This is a major reason for promoting international cooperation in research.)

V. HOW TO IMPLEMENT?

Except for learning about special experiments or demonstration projects, it is usually best to study the implementations of educational computing which are "standard" rather than those under exceptional conditions. (It is particularly important when examining the research of others to understand that implementations under special conditions often do not transfer adequately to the more standard or typical environment.

There is, however, a particular value in experiments where under carefully controlled conditions the impact of computers can be

assessed. Similarly, demonstration projects, especially those with large scale "high visibility" or "super projects" can be of value in drawing national attention to the benefits of computer based education.

VI. WHAT ARE RESEARCH PRIORITIES?

A. Evaluation

Many benefits can be gained by investing in evaluation, and making it a customary component of any computer implementation.

Some generalizations can be stated as a result of existing evaluative research. These are

1. The "case study" approach has been particularly valuable in studying initial cases of implementation, where detailed measures or experiments are not feasible.

However an aggrigation of micro-experiences is not enough to give appropriate guidance for macro decisions. Large scale surveys are needed for such decisions.

2. It is important to have well-defined initial criteria as to goals and implementation -- for example, to distinguish between implementation where computers are meant to assist instruction in traditional subjects, as contrasted with implementations for teaching about computer.

3. It is advantageous to understand the cost elements of computer implementation; insufficient research has been done on this. In analyzing costs, consideration should be given to the study of benefits, effectiveness, utility and compatibility.

B. Planning Priorities

Planning is of utmost importance. Points to consider are:

1. What planning should precede computer implementation within a country?

2. How does an educational policy of computer implementation evolve from a national planning policy?

3. What are the relative priorities for investment in computer education?

4. What are preferred teaching methods that take best advantage of computer capabilities?

5. What priorities can be given to international cooperation, for example: sharing expertise in teaching and training methods, developing software, exchanges of teachers and researchers, organizing cooperative evaluation projects, and disseminating the results of research?

Stanford/UNESCO Symposium on Computers in Education

Priority Issues and Recommendations of

The Working Group on Learning

Two decades of experimentation on the potentialities and effects of computers in learning has produced a sizable body of research data in this field. Most of these data address questions of computer effectiveness in the delivery of traditional instructional materials. Two interrelated developments have, however, substantially transformed prevailing conceptions of the appropriate role of computers in education and the consequent cognitive, motivational and social effects that must be monitored. (1) the wide-spread diffusion of computer technologies and applications in commercial and social spheres--now occuring on a global scale, and (2) rapid advances in the quality of programming environments, display technologies and other user-interface features appropriate to educational settings and available at low cost.

In what follows, we present the consensus of the working group on the most serious deficiencies in research to date, research issues which deserve attention in the areas of curriculum, learning theory and future technology applications, and, finally, priority projects for international cooperation.

GAPS AND PROBLEMS IN RESEARCH

Despite energetic research efforts, both past and currently underway, there is little data on many of the most pressing questions, and international research is beset with intractable methodologial problems.

1. In many domains the assessment of the effects of computers on learning is problematic at the moment since we lack reference points for evaluation. Claims of the computer's ability to accelerate intellectual development in children, for instance, have no simple parallels in traditional education.

2. There is currently considerable debate around the effects of generalized use by children of powerful new computer applications on their social and psychological functioning. Most research in this area, however, is characterized by speculation rather than objective evidence. Long term effects are often predicted with no factual basis whatsoever.

3. Evaluations are generally carried out by developers or implementors of a given product or philosophy without the necessary scientific view of realities in the field, particularly in the classroom.

4. Critical mass is seldom obtained in terms of financial, technical and pedagogical resources to permit the large-scale comparative experiments needed in international research.

5. No conceptual framework exists to evaluate the relevance of observations in

compute -saturated environments to computer-scarce ones. In the latter case, it is still unclear what to expect with respect to feasibility, costs, short and long term effects.

These deficiencies in research to date suggest several of the following research questions, many of which could be addressed profitably through international cooperative efforts.

IMPACTS OF COMPUTERS ON WHAT IS LEARNED

The introduction of "computer literacy," variously defined, as an educational priority has been the first impact on the curriculum in many countries. Our present knowledge of the broad impacts of computerization on commerial and scientific endeavors suggests that every society should at least consider the possibility of a major overhaul of the curriculum in many disciplines. Several questions in the area of the potential impacts of computers on what is learned in schools deserve particular attention:

1. In situations where computer literacy is a goal, what are the differential benefits associated with alternative strategies for reaching specified objectives. Such strategies include:

   - courses that teach about computers
   - courses in computer programming
   - experience acquired with CAI in traditional school subjects
   - experience with utility software and applications
   - mass-mediated information on computer technology and applications

2. What are the curriculum changes occurring in various countries as computers begin to serve diverse roles in social and economic spheres?

3. Are there intellectual skills which are made more important or less important by the advent of computer-based technology? If so, what are they?

4. What changes in knowledge requirements are introduced at the elementary and secondary level by the impact of computers on the nature and evolution of various disciplines?

5. What results have been obtained with the use of specific computer applications to facilitate the learning of abstract concepts in particular disciplines? (For instance, in mathematics, what are the effects of using spread-sheets to introduce the notion of variablility.)

6. To what degree are differing types of computer applications in learning more or less appropriate at each educational level?

EFFECTS OF COMPUTERS ON APPROACHES TO LEARNING AND TEACHING

From the earliest applications of computers in education, the computer was seen as a vehicle for profound changes in the way learning would proceed. Our new-found ability to manipulate the strategies, environments and pace of learning activities through computer software has both reasserted the necessity of and provided the means for resolving fundamental questions regarding the processes of teaching and learning. Research questions fall into the areas of learning theory, requisite skills, and the relation between software design and the educational setting.

1. To what degree is there a cross-cultural consensus on objectives which could be reached in learning with computers.

2. What are the differential effects of computer-mediated learning strategies and software which are based on competing models of human learning?

3. What cross-cultural differences exist in the effects of reinforcement by computers as compared with such feed-back provided by a human teacher.

4. To what degree, if any, can computer programming experiences accelerate intellectual development in young children?

5. To what extent can computer mediation of learning be expected to enhance childrens' intrinsic motivation for learning, and how does this vary from one socio-cultural context to another?

6. What is the minimum of new knowledge required to enable teachers to meet their own pedagogical objectives through examining, using, criticizing and exchanging software, which may be only partially appropriate?

7. What are the most robust models of teacher-computer-student interaction in educational contexts and how does their utility vary with educational goals, subject matter and resource factors?

8. How is the use of computer tools for text-, graph- or problem-solving, word-processing and communication changing the nature of teaching and learning activities in computer-rich educational environments?

9. In what ways should the role of the teachers be reconceptualized in the con-

text of various scenarios of computer-mediated learning, inside and outside of the classroom?

10. To what degree and in what ways can software and documentation designed for stand-alone use by individuals be used efficiently in classroom environments?

11. What are the appropriate models for the development of software and hardware for large-group use in the classroom?

NEW TECHNOLOGY

Technological developments relevant o the potential of computer applications in learning are occurring in the following areas:

- computer networks
- software distribution via telecommunication systems
- computer-managed interactive video
- computer voice input and output
- low-cost large-scale memory devices
- natural language processing
- expert systems
- intelligent authoring systems
- intelligent tutoring systems

Advances in these areas can potentially enhance the quality of interaction with learning material. Several of these developments represent the first fruits of over one-quarter century of research into artificial intelligence (AI). AI developments, particu-

larly in the area of intelligent tutoring systems, will largely determine the future potential of computer-mediated learning.

The rapid rate of technical change in the computer field suggests the need for the development of international resource centers in the UNESCO regions where such technological developments could be monitored and evaluated. Key issues are:

1. What is the potential significance of each development for improving the educational process in both developed and developing nations?

2. To what degree are these developments transferable, or subject to adaptation, to educational settings with differing cultures and resource constraints?

3. To what degree might these developments affect the physical configuration of the educational system?

4. To what degree might these developments affect the distribution of costs and benefits in education?

5. What are the priority domains or subject areas for the development of intelligent systems for learning?

METHODOLOGICAL ISSUES AND PRIORITY PROJECTS FOR INTERNATIONAL COOPERATION

International collaboration in research on computers in learning is unavoidably faced with methodological challenges both with respect to the assessment of impacts and the evaluation of potential applications.

It is apparent that further evaluation of the effects of computers on learning is needed to distinguish between what may be classed as beliefs as opposed to well founded experimental observations. Evaluation should involve both formative and summative methods and be carried out by independent researchers.

Many current assessment devices currently in use were developed to study learning processes in traditional contexts using old technologies. They are often unnecessarily culture-dependent. Attention should be given to the development of relatively culture-independent assessment instruments which will allow cross-cultural comparisons. They should allow measurements of both specific knowledge and competence outcomes as well as general motivational and sociocultural impacts.

Evaluation criteria applied to technological advances in computer-based applications for learning are largely based on market factors, cost factors and social objectives which prevail in a few industrialized countries. In consequence, many developments are only narrowly relevant to certain learning environments and educational objectives. There is an urgent need for the formulation of evaluation criteria based on learning environments which are broadly applicable in the international community.

We propose three practical projects in which international collaborative efforts would be immediately useful:

1. A program to collect and disseminate parallel detailed descriptions of implementation processes and observed outcomes of noteworthy experiments on computers in learning in all Unesco member countries.

   In most developing countries there is no systematic strategy for the use of computers in learning. At the same time the international research community must obtain a clear picture of the nature of the computer-based interventions taking place in order to develop informed recommendations regard-

ing research and policy. The case-study approach, emphasizing ethnographic methods and process analysis seems most appropriate at this stage, as it is essential to capture the cultural, economic and political factors which may largely shape the nature of early implementations.

2. A cross-cultural multi-year study of the effects of programming experiences at the elementary and secondary school levels.

We currently have inadequate information about the long-term consequences of the use of computers in learning. The need for comparability across experiments suggests that a single programming language should be chosen for study. The Logo programming language and learning environment is a case of a fully promoted application which has clearly specified and highly appealing theoretical objectives. It has implications both for the philosophy of education and the childhood acquisition of generalizable intellectual skills. Such a study of Logo could address many of the research questions raised in our deliberations.

3. A research and development project which brings together experts from industrialized and non-industialized countries to contribute to the design and evaluation of an intelligent tutoring system (ITS).

The enormous investment of time required in the development of an ITS means that relatively few will be designed. It is in the interest of the international community that these systems be broadly relevant and accessable. Collaboration between researchers from developed and less developed countries would allow developers of these systems to take into account a richer

and more representative set of students' conceptual problems and contextual reference points, and would result in systems which have greater utility to educators in developing countries.

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